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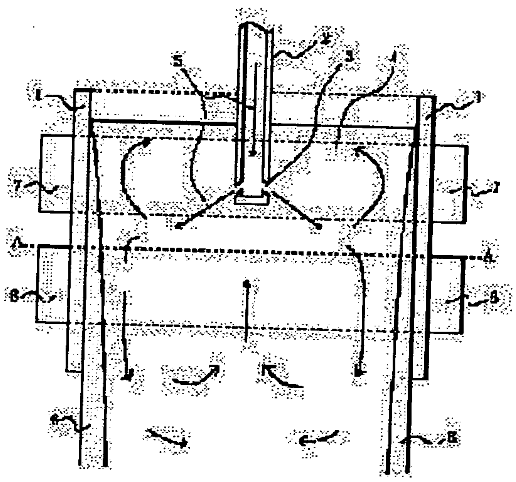
(71)Applicant : NIPPON STEEL CORP
(72)Inventor : MIYAZAWA KENICHI
HARADA HIROSHI
MOROHOSHI TAKASHI

(54) METHOD FOR REDUCING NON-METALLIC INCLUSION IN CONTINUOUS CASTING

(57)Abstract:
PROBLEM TO BE SOLVED: To reduce the inclusion on the surface and in the inner part of a cast slab even in the case of being quick casting speed by casting plural kinds of steels having different harmfulness of the inclusion, in a continuous casting.
SOLUTION: Electromagnets 7 for electromagnetic stirring are arranged on a mold part 1 at the upper part from the lower end part of an immersion nozzle 2, and electromagnetic devices 8 for impressing shifting magnetic field and static magnetic field to molten steel are arranged on the mold part at the lower part from the lower end of the immersion nozzle. The non-metallic inclusion in the cast slab is reduced by electromagnetic-stirring the molten steel at both of the upper part and the lower part in the mold or by electromagnetic-stirring to the upper part and impressing the static magnetic field to the lower part according to the kind of steel and the casting speed.



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(71)出願人 000006655
新日本製鐵株式会社
東京都千代田区大手町２丁目６番３号

(72)発明者 宮沢 憲一
富津市新富20－１ 新日本製鐵株式会社技術開発本部内

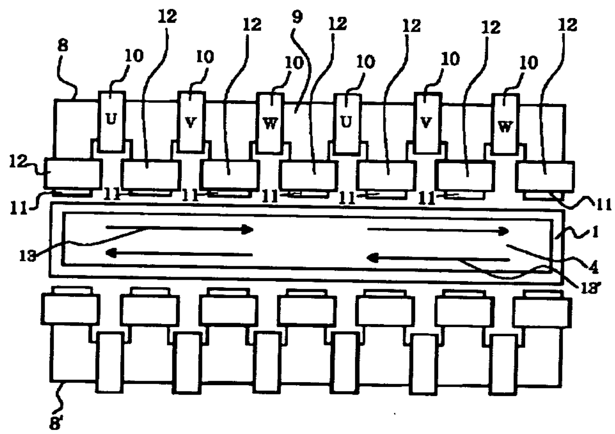
(72)発明者 原田 寛
富津市新富20－１ 新日本製鐵株式会社技術開発本部内

(72)発明者 諸星 隆
富津市新富20－１ 新日本製鐵株式会社技術開発本部内

(74)代理人 弁理士 田中 久喬

(54)【発明の名称】連続鋳造における非金属介在物の低減方法

(57)【要約】
【課題】 連続鋳造において、介在物の有害性が異なる複数の鋼種を鋳造し、鋳造速度が速くても、鋳片表層の介在物および鋳片内部の介在物を低減する。
【解決手段】 浸漬ノズル２の下端よりも上部の鋳型部１に電磁撹拌用の電磁石７を設置し、かつ該浸漬ノズルの下端より下方の鋳型部に移動磁界および静磁場を溶鋼に印加する電磁石装置８を設置して、鋼種や鋳造速度に応じて、鋳型内の上部と下部の両方の溶鋼を電磁撹拌したり、または、上部を電磁撹拌し下部では静磁場を印加して鋳片の非金属介在物を低減する。



【特許請求の範囲】

【請求項１】　鋼の連続鋳造において、溶鋼を浸漬ノズルを経て鋳型内へ注湯して鋳片を製造する際、浸漬ノズルの下端よりも上部の鋳型部に電磁撹拌用の電磁石を設置し、かつ該浸漬ノズルの下端より下方の鋳型部に移動磁界および静磁場を溶鋼に印加する電磁石装置を設置して、鋼種や鋳造速度に応じて、鋳型内の上部と下部の両方の溶鋼を電磁撹拌したり、または、上部を電磁撹拌し下部では静磁場を印加して鋳片の非金属介在物を低減することを特徴とする連続鋳造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、溶鋼の連続鋳造方法に関する。

【０００２】

【従来の技術】鋼の連続鋳造では、一つの連鋳機で種々の鋼種を鋳造する。薄板用の鋼種の中には、薄板製品の外観や品質を向上させる目的から、鋳片の表面近くに存在する比較的大きな非金属介在物や気泡を極力低減させたい鋼種や、一方、薄板製品の加工性をあげるために鋳片内部の介在物を極力低減したい鋼種があり、これらの鋼種を一台の同じ連鋳機で鋳造しているのが現状である。

【０００３】従来、鋳片表面近傍の介在物を鋳型内で低減する方法として、鋳型内の凝固シェルの先端に溶鋼流動を付与して、その洗浄効果により凝固シェルへの介在物の捕捉を抑制するため、鋳型部の上部に設置した電磁石によって溶鋼に移動磁界を印加し、凝固シェル先端に沿った水平方向の撹拌流動を誘起させる方法が知られており、特願平４－１３４８９８公報や特願平４－１５９８０２公報では鋳型内の溶鋼に移動磁界を印加して撹拌する方法を開示している。スリバー疵等の薄板製品の表面疵を防止するためには、鋳片厚さや薄板製品の厚さによって異なるが、鋳片表面から約２５ｍｍ程度までの厚さ領域における比較的大きな介在物や気泡を低減しなければならない。このため、鋳造速度が遅い場合、鋳型上部に設置した電磁石で鋳片表層の介在物を低減することが可能であるが、鋳造速度が早くなると、鋳型上部の電磁石による撹拌効果が発揮できる鋳片表層厚さが薄くなるため、完全に薄板表面疵を防止することができない。

【０００４】一方、鋳片内部の非金属介在物の低減については、鋳型内の溶鋼に静磁場を印加し、浸漬ノズルの吐出孔よりも下方へ流れる下向き流の浸透深さを低減することにより、溶鋼内の介在物が鋳片内部へ捕捉されることを抑制することができ、溶鋼に静磁場を印加して溶鋼流動を制動する方法は特願昭６２－２４１４３９号公報や特願平４－１２７９３８号公報で開示されている。

【０００５】しかし、一台の同じ連鋳機で、鋼種や鋳造速度に応じて、鋳片表層の介在物や気泡を問題ないレベルまで低減したり、鋳片内部の介在物を問題ないレベルまで低減できるような鋳造方法が無いのが実状である。

【０００６】

【発明が解決しようとする課題】一台の連続鋳造機において、介在物の有害性が異なる複数の鋼種を鋳造し、鋳造速度が速くても、鋳片表層の介在物の量を低減したり、鋳片内部の介在物の量を低減する効率的な連続鋳造を安定に行うことが課題である。

【０００７】

【課題を解決するための手段】本発明者らは、上記課題を解決するために種々検討した結果、鋳型上部に移動磁界を溶鋼に印加する電磁石装置を設置し、一方、鋳型の下部には、一つの電磁石装置によって移動磁場を印加して溶鋼を撹拌させたり、静磁場を印加して溶鋼を制動できる電磁石装置を設置することにより、鋳片表層の介在物を低減でき、かつ、鋳片内部の介在物も低減できることを見い出した。

【０００８】本発明の要旨は、鋼の連続鋳造において、溶鋼を浸漬ノズルを経て鋳型内へ注湯して鋳片を製造する際、浸漬ノズルの下端よりも上部の鋳型部に電磁撹拌用の電磁石を設置し、かつ該浸漬ノズルの下端より下方の鋳型部に移動磁界および静磁場を溶鋼に印加する電磁石装置を設置して、鋼種や鋳造速度に応じて、鋳型内の上部と下部の両方の溶鋼を電磁撹拌したり、または、上部を電磁撹拌し下部では静磁場を印加して鋳片の非金属介在物を低減することを特徴とする連続鋳造方法である。

【０００９】

【発明の実施の形態】図１は、連続鋳造において、浸漬ノズル２の吐出孔３を経て溶鋼４を鋳型１の中へ注湯する際、鋳型部の上部に移動磁界を溶鋼に印可するための電磁石装置７を設置し、鋳型部の下部に移動磁界と静磁場を溶鋼に印可するための電磁石装置８を設置した時の縦断面図を示す。浸漬ノズルの吐出孔は、通常、水平方向よりも下向きになっており、電磁石装置を作動させない場合、鋳型内へ注湯された溶鋼のノズル吐出流は、鋳片の短片側の凝固シェル６に衝突して、ノズルの吐出孔よりも下方へ流れる下向き流と、吐出孔よりも上へ流れる上向き流に分かれる。溶鋼は鋳型への抜熱により凝固し、凝固シェルは連続的に下方へ引き抜かれる。下向き流の速度が余りにも大きいと、吐出流の浸透深さが深くなるため、非金属介在物の浮上除去にとって不利となり、鋳片の内部に介在物が多く残り、鋼製品の品質に悪影響を及ぼす。

【００１０】炭素濃度が約３０－４０ｐｐｍ以下の極低炭素鋼の場合、鋳片表層の比較的大きな介在物や気泡が薄板製品の表面疵の起因となる場合があるため、鋳片表層の介在物や気泡を極力低減しなければならない。そのため、図１に示す鋳型上部の電磁石７を使って溶鋼に移動磁場を印可すると、凝固シェルに沿った水平方向の溶鋼の流動が誘起され、凝固シェル付近で介在物や気泡が

洗い流され、凝固シェルへの比較的大きな介在物や気泡の捕捉が低減する。鋳型上部での電磁撹拌は、余りにも強すぎると、溶鋼のメニスカス状の鋳造用フラックスが溶鋼に巻き込まれることになり、鋳片内の非金属介在物が増加する原因となるため、移動磁界印可の際の電磁撹拌による溶鋼流速は、フラックス巻き込みの弊害が生じない約０．４－０．６ｍ／ｓ以下の流速に抑える必要がある。鋳造速度が速くなると、鋳型部で形成される凝固シェルの厚さは薄くなり、鋳型上部の電磁石装置７による介在物や気泡の低減効果が享受できる鋳片表層厚さが薄くなる。そのため、鋳片表層の介在物や気泡の除去が重要な極低炭素鋼では、速い鋳造速度の場合、上部の電磁石７に加え、下部の電磁石装置８も同時に使って溶鋼に移動磁界を印可し、凝固シェルに沿って溶鋼流動を付与すると、鋳片表層の約３０ｍｍ厚さまでの介在物や気泡が低減でき、薄板表面疵の防止が可能となる。なお、鋳片内部の介在物が薄板製品に悪影響を及ぼすことは比較的少ない。

【００１１】一方、ブリキ製品に使われる低炭アルミキルド鋼などのように、鋳片表面の大型介在物のみならず、鋳片内部の非金属介在物の低減を厳格に行わねばならない鋼種を鋳造する場合、鋳型上部の電磁石装置を使って鋳片表層の介在物や気泡を低減し、同時に鋳型下部の電磁石装置８を使って、溶鋼に静磁場を印加すると、静磁場中を流動する溶鋼に、溶鋼の流動の方向と逆方向へ電磁気力が作用し、溶鋼の流速が低下する。このため、吐出流の浸透深さが大幅に低減し、非金属介在物が溶鋼プールの深い位置まで侵入せず、メニスカスへの浮上除去が促進される。

【００１２】図２は、図１のＡ－Ａの位置の水平断面の模式図であり、鋳型の下部において鋳型１を挟んで一定の間隔を保って対向配置された一対の電磁石８および８’を示す。電磁石８と８’の構成や機能は同じである。電磁石８は、鉄芯９、鉄芯から枝別れした磁極１１、鉄芯に巻かれた複数のコイル１０、枝別れした磁極の鉄部分に巻かれたコイル１２から構成される。次に説明するように、コイル１０や１２に流す電流を変えることにより、鋳型内の溶鋼に移動磁界や静磁場を印加することができる。

【００１３】移動磁界の印加方法については、図２において、コイル１０の隣接した３個のコイルｕ、ｖ、ｗに、交流電流の位相を１２０度づつずらした３相の交流電流を流すと、コイルｕ、ｖ、ｗに流す電流の経時変化に応じて、各磁極１１の先端から鋳型内の溶鋼に印加される磁界は時間的に変化し、磁極に近い溶鋼に移動磁界が作用することになり、この移動磁界の作用により溶鋼の流れ１３が生じる。同様な方法で鋳型の対面側でも溶鋼の流れ１３’を生起させることができ、鋳型内の溶鋼が撹拌されることになる。同様に、図２に示した構造の電磁石を鋳型上部に設置し、鋳型上部の溶鋼に移動磁界を印可して溶鋼撹拌を行うことができる。

【００１４】溶鋼に静磁場を印加する場合、２図に示した電磁石装置の場合には、コイル１２へ直流電流を流す方法があり、コイル１２に流す直流電流の向きを任意に変えることにより、図３に示すように、磁極の極性がＮ極とＳ極の交互の配置にすることができる。磁界は、Ｎ極からＳ極へ向かうため、鋳型の対面側の磁極の極性をＮ極とＳ極の交互の配置とすると、鋳型内の溶鋼にＮ極からＳ極へ向かう静磁場が印加でき、この静磁場の中を溶鋼が流動すると、流動の方向と反対側に電磁気力が作用し、溶鋼の流動が抑制される。

【００１５】

【実施例】スラブの連続鋳造において、図１に示すように鋳型の上部と下部に電磁石を設置し、鋳片内の非金属介在物に及ぼす鋳型上下部での移動磁界印加の場合の効果、および鋳型上部は移動磁界印可で下部は静磁場印加の場合の効果を調べる実験を行った。通常の銅鋳型を使った連続鋳造機で、モールドフラックスを用いた鋳造実験において、スラブ鋳片のサイズは厚さ１７０ｍｍ、幅８００ｍｍで、鋳型の長さは８００ｍｍ、ノズル吐出孔の位置はメニスカスから２５０ｍｍ下である。鋳型上部の電磁石に関し、鋳造方向における電磁石の中心位置はメニスカスから１００ｍｍで、移動磁場印可のために電磁石に約５００Ａの３相交流電流を流した。一方、鋳型下部の電磁石については、磁石の中心位置がメニスカスから４００ｍｍ下になるように設置し、移動磁界を印可する場合にはコイルに約５００Ａの電流を流し、静磁場を印可する場合には、図２のコイル１２に直流電流を流すことにより、磁場強度が約０．３テスラの磁場を発生させた。

【００１６】炭素濃度が約３０ｐｐｍの極低炭素鋼を使い、異なった鋳造速度において鋳片表層の非金属介在物の量に及ぼす鋳型の上部と下部における移動磁界印可による溶鋼撹拌の効果を調べる鋳造実験を行った。鋳造実験後、鋳片長辺側の表面から５ｍｍ間隔で鋳片表面に平行な面を顕微鏡観察し、鋳片表層における１０μｍ以上の介在物の個数（個／cm^2）を調査した。その結果、鋳造速度が１ｍ／ｍｉｎの場合には、介在物個数が約１．０個／cm^2以下と少なくなる鋳片表層の厚さは、上部の電磁石のみを作動させた場合には約２５ｍｍ厚さであり、上部と下部の電磁石を作動させた場合には、約３０ｍｍ厚さとなり、上下両方の電磁石を使った方が、介在物の量を少なくしなければならない鋳片表層領域が厚くなることが分かった。なお、電磁石の効果が及ばない鋳片内部での介在物量は、約１．５から２．０個／cm^2程度であった。また、鋳造速度が１．６ｍ／ｍｉｎと速い場合、介在物個数が約１．０個／cm^2以下と少なくなる鋳片表層の厚さは、上部の電磁石のみを作動させた場合には約１５ｍｍ厚さであり、上部と下部の電磁石を作動させた場合には、約２５ｍｍ厚さとなり、鋳造

速度が速くなっても上下両方の電磁石を使うことにより、介在物の量を少なくしなければならない鋳片表層領域の厚くを確保できることが分かった。

【0017】次に、炭素濃度が０．０１％のアルミキルド鋼を使って、鋳型の上部で移動磁界印可による溶鋼撹拌を実施し、一方、鋳型の下部では静磁場を印加して鋳造実験を行い、鋳片内の介在物の量を調査した。鋳造速度は１．６ｍ／ｍｉｎとし、電磁石の使用の有無による介在物量の違いを検討した。その結果、鋳片表面から２０ｍｍまでの鋳片表層の介在物量は、上下部の電磁石を作動させない場合には約１．５個／ｃｍ²と多いの比較し、電磁石を作動させると０．８５個／ｃｍ²と少なくなり、特に上部の電磁撹拌の効果によると思われる鋳片表層の介在物の量の低減が確認できた。鋳片内部の介在物量については、鋳片の上面側の１／４厚さの位置における介在物量が、上下部の電磁石の作動がない場合には２．１個／ｃｍ²であるのに対し、上下部の電磁石を作動させると１．３個／ｃｍ²にまで低減し、下部の電磁石による静磁場の印可により、溶鋼の吐出流が静磁場の印可により深くまで侵入せず、鋳片内部への介在物の捕捉が少なくなり、鋳型内における介在物の浮上除去が促進されたことが判明した。

【0018】以上のように、鋼種や鋳造速度に応じて、鋳型上部の電磁石により溶鋼を撹拌し、かつ鋳型下部の電磁石を使って溶鋼に移動磁界や静磁場を印加することにより、鋳片表層の介在物や鋳片内部の介在物を低減することが可能であることが分かった。

【0019】

【発明の効果】本発明を実施すれば、一台の連続鋳造機において、鋳造速度が速くても、鋳片表層の介在物を低減したり、また鋳片内部の介在物を低減して、効率的な連続鋳造を安定に行うことができる。

【図面の簡単な説明】

【図１】浸漬ノズル、鋳型、電磁石装置の関係を示す縦断面図である。

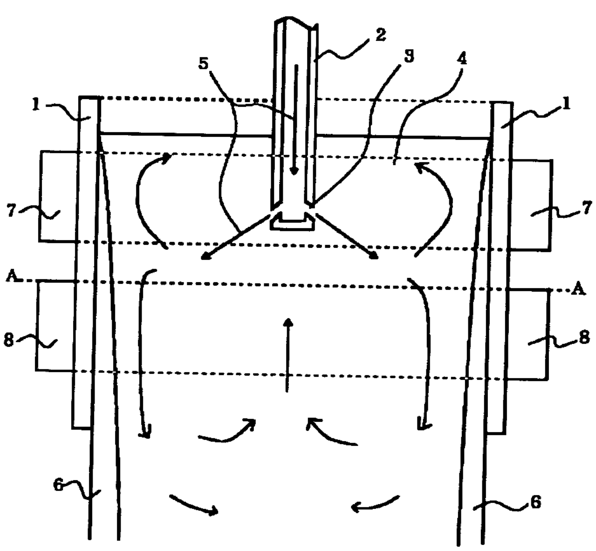
【図２】図１のＡ－Ａの位置の平面図であり、鋳型を挟んで設置した電磁石装置の模式図である。

【図３】電磁石の磁極の極性が鋳型の両側で交互に対称な場合の模式図である。

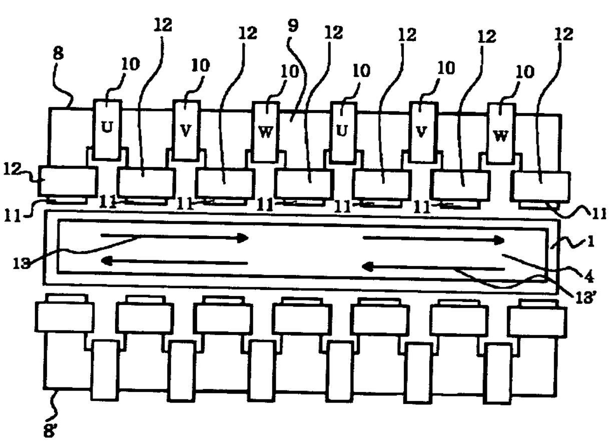
【符号の説明】

1　鋳型
2　浸漬ノズル
3　吐出孔
4　溶鋼
5　溶鋼の流れる方向
6　凝固シェル
7　電磁撹拌用電磁石
8、8’　移動磁界印可および静磁場印可の兼用電磁石
9　鉄芯
10　コイル
11　磁極
12　コイル
13、13’　溶鋼の撹拌方向

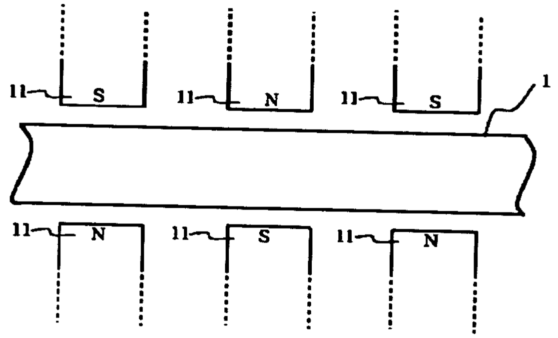
【図１】



【図２】



【図３】



Japanese Patent Laid-Open No. 262651/1997
Laid-Open Date : October 7, 1997
Application No. : 97331/1996
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Inventors : Ken-ichi Miyazawa, Hiroshi Harada and Takashi Moroboshi
Applicant : Nippon Steel Corporation

Title of the Invention: METHOD FOR DECREASING NONMETALLIC INCLUSIONS IN A CONTINUOUS CASTING

[Abstract]

[Matters to Solve]

In a continuous casting, a plurality of steel species where harmfulness of inclusions is different are cast and, even when the casting rate is quick, inclusions on the surface layer of cast piece and inclusions inside the case piece are decreased.

[Solving Means]

An electromagnet 7 for electromagnetic stirring is installed in a template part 1 which is upside from the lower end of a submerged nozzle 2 and also an electromagnet device 8 which applies mobile magnetic field and static field to melted steel is installed in

a template part which is below the lower end of the said submerged nozzle whereby, depending upon steel species and casting rate, both melted steels in upper and lower parts in the template are electromagnetically stirred or the upper part is electromagnetically stirred while the lower part is applied with static magnetic field whereby nonmetallic inclusions in the cast piece are decreased.

[Claims]

1. A continuous casting method, characterized in that, in the manufacture of cast pieces by pouring the melted steel into a template via a submerged nozzle in a continuous casting of steel, an electromagnet for electromagnetic stirring is installed in a template part which is upside from the lower end of a submerged nozzle and also an electromagnet device which applies mobile magnetic field and static field to melted steel is installed in a template part which is below the lower end of the said submerged nozzle whereby, depending upon steel species and casting rate, both melted steels in upper and lower parts in the template are electromagnetically stirred or the upper part is electromagnetically stirred while lower part is applied with static magnetic field whereby nonmetallic

inclusions in the cast piece are decreased.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a continuous casting method for melted steel.

[0002]

[Prior Art]

In a continuous casting of steel, various steel species are manufactured using a continuous casting machine. Among the steel species for thin plates, there is a steel species where relatively big nonmetallic inclusions and foams existing near the surface of the cast piece are aimed to be decreased as much as possible with an object of improving the appearance and quality of the thin plate product while there is another steel species where the inclusions inside the cast piece are aimed to be decreased as much as possible with an object of enhancing the processing ability of the thin plate products. The current state is that those steel species are cast by the same continuous casting machine.

[0003]

With regard to a method for decreasing the inclusions near the surface of steel piece in a template,

there has been known a method where a melted steel flow is applied to the front end of a coagulation shell in a template and, in order to suppress the trapping of the inclusions into the coagulation shell by the washing effect, mobile magnetic field is applied to the melted steel by electromagnet installed on the upper part of the template part whereby a stirring flow in a horizontal direction along the front end of the coagulation shell is induced and, in the Japanese Patent Application Nos. 134898/1992 and 159802/1992, there is disclosed a method where mobile magnetic field is applied to the melted steel in a template resulting in stirring. For the prevention of surface scratch on the thin plate products such as sliver scratch, there is a need of decreasing the relatively big inclusions and foams in a region from the surface of the cast piece to about 25 mm thickness although that may differ depending upon thickness of the cast piece and thickness of the thin plate product. When the casting rate is slow, it is possible to decrease the inclusions on the surface layer of the cast piece by electromagnet installed on the upper part of the template. However, when the casting rate is quick, the surface layer thickness of the cast piece where the stirring effect by the electromagnet on the upper part of the template is achieved becomes thin whereby it is not possible to

completely prevent the scratch on the surface of the thin plate.

[0004]

On the other hand, with regard to a decrease of nonmetallic inclusions inside the cast piece, static magnetic field is applied to the melted steel in the template and the depth of penetration of downward flow which flows downward from the discharge hole of a submerged nozzle is decreased whereby trapping of the inclusions in the melted steel into the inner area of the cast piece can be suppressed. In the Japanese Patent Application Nos. 241439/1987 and 127938/1992, there is disclosed a method where static magnetic field is applied to the melted steel whereby the flow of the melted steel is suppressed.

[0005]

However, it is the current state that there is no casting method where inclusions and foams on the surface layer of the cast piece are decreased to such a level that no problem is resulted and inclusions inside the cast piece is decreased to such a level that no problem is resulted depending upon the steel species and the casting rate using one continuous casting machine.

[0006]

[Matter that the Invention is to Solve]

The matter which is to solve is that, in one continuous casting machine, there is carried out an efficient continuous casting in a stable manner where a plurality of steel species in which harmfulness of the inclusions is different are cast and, even if the casting rate is quick, amount of the inclusions on the surface layer of the cast piece is decreased or amount of the inclusions inside the cast piece is decreased.

[0007]

[Solving Means]

In order to solve the above-mentioned matter, the present inventors have carried out intensive investigations and found that the inclusions on the surface layer of the cast piece can be decreased and the inclusions inside the cast piece can be also decreased when an electromagnet device which applies mobile magnetic field to the melted steel is installed on the upper part of the template while, on the lower part of the template, there is installed an electromagnet device which is able to stir the melted steel by application of mobile magnetic field or is able to control the melted steel by application of static magnetic field.

[0008]

A gist of the present invention is a continuous casting method, characterized in that, in the manufacture

of cast pieces by pouring the melted steel into a template via a submerged nozzle in a continuous casting of steel, an electromagnet for electromagnetic stirring is installed in a template part which is upside from the lower end of a submerged nozzle and also an electromagnet device which applies mobile magnetic field and static field to melted steel is installed in a template part which is below the lower end of the said submerged nozzle whereby, depending upon steel species and casting rate, both melted steels in upper and lower parts in the template are electromagnetically stirred or the upper part is electromagnetically stirred while the lower part is applied with static magnetic field whereby nonmetallic inclusions in the cast piece are decreased.

[0009]

[Mode for Carrying Out the Invention]

Fig. 1 shows a longitudinal cross section where, in pouring the melted steel 4 into a template 1 via a discharge hole 3 of a submerged nozzle 2 in a continuous casting, an electromagnet device 7 for applying mobile magnetic field to the melted steel is installed on the upper part of the template part while, on the lower part of the template part, an electromagnetic device 8 for applying mobile magnetic field and static magnetic field to the melted steel is installed. Usually, the discharge

hole of the submerged nozzle is in a downward look from the horizontal direction and, when the electromagnet device is not operated, a discharged flow from the nozzle of the melted steel poured into the template collides against the coagulation shell 6 at the shorter side of the cast piece and divided into a downward flow which flows downward from the discharge hole of the nozzle and a upward flow which flows upward from the discharge hole. Melted steel is coagulated by removal of heat to the template and the coagulation shell is pulled out downward continuously. When the speed of the downward flow is too quick, the depth of penetration of the discharged flow becomes deep and that is disadvantageous to floating and removal of the nonmetallic inclusions whereby many inclusions remain inside the cast piece which badly affect the quality of the steel products.

[0010]

In the case of extremely low carbon steel where the carbon concentration is not more than about 30~40 ppm, relatively big inclusions and foams on the surface layer of cast piece may cause the surface scratch of the thin plate product and, therefore, inclusions and foams on the surface layer of the cast piece should be decreased as much as possible. When mobile magnetic field is applied to the melted steel using an electromagnet 7 on

the upper part of the template as shown in Fig. 1 for such a purpose, flow of the melted steel in a horizontal direction along the coagulation shell is induced and the inclusions and foams are washed out near the coagulation shell whereupon trapping of the relatively big inclusions and foams by the coagulation shell decreases. When the electromagnetic stirring on the upper part of the template is too strong, meniscus-like flux for casting of melted steel is trapped by the melted steel causing an increase of nonmetallic inclusions in the cast piece and, therefore, the flow rate of the melted steel by electromagnetic stirring upon application of mobile magnetic field is to be suppressed to a flow rate of not more than about 0.4 to 0.6 m per second so that disadvantage of trapping of the flux is not resulted. When a casting rate is quick, thickness of the coagulation shell formed in the template part becomes thin and the surface layer thickness of the cast piece which is able to enjoy the effect of decreasing the inclusions and foams by the electromagnet device 7 on the upper part of the template becomes thin. Therefore, in an extremely low carbon steel where removal of inclusions and foams on the surface layer of cast piece is important, the electromagnet device 8 on the lower part is used together with the electromagnet 7 on the upper part for applying

mobile magnetic field to the melted steel and applying a melted steel flow along the coagulation shell in the case of a quick casting rate whereupon it is possible to decrease the inclusions and foams on the surface layer of the cast piece for the thickness of about 30 mm and to prevent the scratch on the surface of thin plate. Incidentally, it is relatively rare that the inclusions inside the cast piece badly affect the thin plate product.

[0011]

On the other hand, when inclusions and foams on the surface layer of cast piece are decreased using an electromagnetic device on the upper part of the template and, at the same time, static magnetic field is applied to the melted steel using an electromagnet device 8 at the lower part of the template in casting the steel species where decrease of nonmetallic inclusions inside the cast pieces is to be strictly carried out such as in the case of low-carbon aluminum-killed steel used for tin plate products, the electromagnetic force acts on the melted steel flowing in the static magnetic field in the direction opposite to the direction of flow of the melted steel whereby the flow rate of the melted steel lowers. As a result, the depth of penetration of the discharged flow greatly decreases, the nonmetallic inclusions do not invade the deep position of the melted

steel pool and its removal by floating to the meniscus is promoted.

[0012]

Fig. 2 is a scheme of a horizontal cross section at the position of A-A of Fig. 1 and shows a pair of electromagnets 8 and 8′ which are oppositely placed with a predetermined interval sandwiching the template 1. Constitution and function of those electromagnets 8 and 8′ are same. The electromagnet 8 is constituted from iron core 9, magnetic pole 11 branched from the iron core, a plurality of coils 10 wound around the iron core and coil 12 wound around the iron part of the branched magnetic pole. As will be illustrated hereunder, when the current applied to the coil 10 or 12 is changed, it is possible to apply mobile magnetic field and static magnetic field to the melted steel in the template.

[0013]

Method for the application of mobile magnetic field is that, in Fig. 2, when three-phase alternating current where phases of the alternating current are lagged to an extent of 120° each other is applied to the adjacent coils u, v and w of the coil 10, magnetic field applied to the melted steel in the template from the front end of each magnetic pole 11 changed in terms of time depending upon the change of the current applied to the

coils u, v and w with a lapse of time whereupon the mobile magnetic field acts on the melted steel near the magnetic pole and, as a result of action of the said mobile magnetic field, the flow 13 of the melted steel is resulted. By the same method, it is also possible to cause the flow 13′ of the melted steel at the opposite side of the template whereby the melted steel in the template is stirred. Similarly, it is also possible that the electromagnet having the structure of Fig. 2 is installed on the upper part of the template and mobile magnetic field is applied to the melted steel in the upper part of the template to stir the melted steel.

[0014]

With regard to a method for applying the static magnetic field to the melted steel, there is a method in the case of the electromagnet device as shown in Fig. 2 where direct current is applied to the coil 12 and, when the direction of the direct current applied to the coil 12 is changed, it is possible as shown in Fig. 3 that polarity of the magnetic pole is made N pole and S pole alternately. The magnetic field comes from N pole to S pole and, therefore, when the polarity of the magnetic pole of the opposite side of the template is made N pole and S pole alternately, static magnetic field from N pole to S pole can be applied to the melted steel

in the template and, when the melted steel flows in this static magnetic field, electromagnetic force acts in the direction opposite to the flow direction whereupon flow of the melted steel is suppressed.

[0015]

[Examples]

In a continuous casting of slab, an experiment was carried out for checking the effect on the nonmetallic inclusions in the cast piece in the case of applying mobile magnetic field on the upper and lower parts of the template when electromagnets were installed on the upper and lower parts of the template as shown in Fig. 1 and also for checking the effect in the case where mobile magnetic field was applied to the upper part of the template while static magnetic field was applied to the lower part thereof. In a casting experiment using a mold flux in a continuous casting machine using a common copper template, size of the slab cast piece was 170 mm thickness and 800 mm width, length of the template was 800 mm and position of the discharge hole of nozzle was 250 mm below the meniscus. With regard to the electromagnet on the upper part of the template, the central position of the electromagnet in the casting direction was 100 mm from meniscus and, for application of mobile magnetic field, three-phase alternating current of about 500 A was

applied to the electromagnet. On the other hand, with regard to the electromagnet on the lower part of the template, the center position of the electromagnet was placed at 400 mm below the meniscus and, when mobile magnetic field was applied, electric current of about 500 A was applied to the coil while, when static magnetic field is applied, direct current was applied to the coil 12 of Fig. 2 whereby a magnetic field of about 0.3 Tesla of magnetic field intensity was generated.

[0016]

An extremely low carbon steel where carbon concentration was about 30 ppm was used and a casting experiment was carried out for checking the effect of stirring of melted steel by application of mobile magnetic field at the upper and lower parts of the template on the amount of nonmetallic inclusions on the surface of cast piece at different casting rates. After the casting experiment, surfaces parallel to the cast piece surface with interval of 5 mm from the surface of the long side of the cast piece were observed under a microscope and the numbers (per cm^2) of the inclusions having a size of 10 μm or bigger on the cast piece surface were checked. As a result, when the casting rate was 1 m/minute, thickness of the cast piece surface layer where the numbers of the inclusions became as little as not

more than $1.0/cm^2$ was about 25 mm when only the upper electromagnet was operated while, electromagnets of both upper and lower parts were operated, the thickness was about 30 mm whereupon it was found that, when electromagnets of both upper and lower parts were used, the cast piece surface layer region where the amount of the inclusions was to be made little became thick. Incidentally, the amount of the inclusions inside the cast piece where the effect of the electromagnet did not reach was about 1.5 to $2.0/cm^2$. When the casting rate was as quick as 1.6 m/minute, thickness of the cast piece surface layer where the numbers of inclusions became as little as not more than $1.0/cm^2$ was about 15 mm when only the upper electromagnet was operated while, electromagnets of both upper and lower parts were operated, the thickness was about 25 mm. Thus it has been found that, even when the casting rate is quick, the thickness of the cast piece surface layer region where the amount of the inclusions is to be made little can be ensured provided that the electromagnets of both upper and lower parts are used.

[0017]

Then, an aluminum-killed steel where carbon concentration was 0.01% was used and stirring of the melted steel by application of mobile magnetic field on

the upper part of the template was carried out while, on the lower part of the template, a casting experiment was carried out by application of static magnetic field to check the amount of the inclusions in the cast piece. The casting rate was made 1.6 m per minute and the difference in the amount of inclusions among the use and non-use of electromagnet was tested. The result was that the amount of inclusions in the cast piece surface layer until 20 mm from the cast piece surface was as much as about $1.5/cm^2$ when the electromagnets of upper and lower parts were not operated while, when they were operated, they were as little as $0.85/cm^2$ and there was confirmed a decrease of the amount of inclusions in the cast piece surface layer which was presumably due to the effect especially by the electromagnetic stirring of the upper part. With regard to the amount of the inclusions inside the cast piece, amount of the inclusions at the position of 1/4 thickness of the upper surface of the cast piece was $2.1/cm^2$ when electromagnets of upper and lower parts were not operated while, when they were operated, the amount decreased to $1.3/cm^2$. Thus, it has been found that, as a result of application of static magnetic field by the electromagnet of the lower part, discharged flow of the melted steel does not deeply invade by application of static magnetic field whereupon trapping of the

inclusions into the cast piece decreases and removal of the inclusions in the template by floating is promoted.

[0018]

As mentioned hereinabove, it has now been found that inclusions on the surface layer of cast piece or that inside the cast piece are able to be decreased when melted steel is stirred by the electromagnet on the upper part of the template and applied with mobile magnetic field or static magnetic field using the electromagnet on the lower part of the template depending upon the steel species and casting rate.

[0019]

[Advantage of the Invention]

In carrying out the present invention, it is possible to conduct an efficient continuous casting in a stable manner in a continuous casting machine by decreasing the inclusions on the surface layer of the cast piece or by decreasing the inclusions inside the cast piece even if the casting rate is quick.

[Brief Description of the Drawings]

Fig. 1 is a longitudinal cross section showing the relation among submerged nozzle, template and electromagnet device.

Fig. 2 is a plain view of the position of A-A of

Fig. 1 and is a scheme of an electromagnet device installed by sandwiching a template.

Fig. 3 is a scheme when polarity of magnetic pole of the electromagnet is symmetric alternately at both sides of the template.

[Explanation of the symbols]

1 template

2 submerged nozzle

3 discharging hole

4 melted steel

5 direction of flow of the melted steel

6 coagulation shell

7 electromagnet for electromagnetic stirring

8, 8′ electromagnets for application of mobile magnetic field and application of static magnetic field

9 iron core

10 coil

11 magnetic pole

12 coil

13, 13′ direction of stirring of melted steel